# CLHCP 2021

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# Multiplicity dependence of $\Upsilon$ production at forward rapidity in pp collisions at $\sqrt{s} = 13$ TeV with ALICE

Yanchun Ding[1,2] for the ALICE Collaboration

Central China Normal University[1], Institut de Physique des Deux Infinis de Lyon[2]

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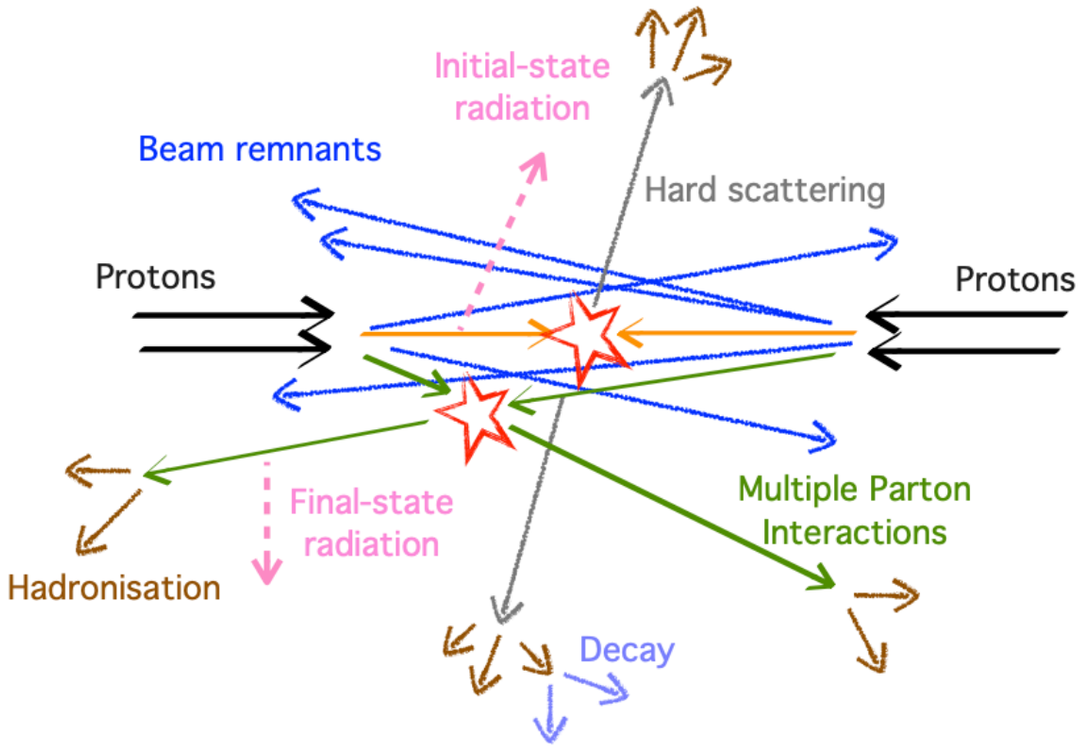
# PHYSICS MOTIVATIONS

Quarkonium: bound state of $c\bar{c}$ [e.g. J/ψ and ψ(2S)] or $b\bar{b}$ pair [e.g. $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$]

Charged-particle multiplicity: the number of primary charged particles produced in the collisions in a given pseudorapidity window



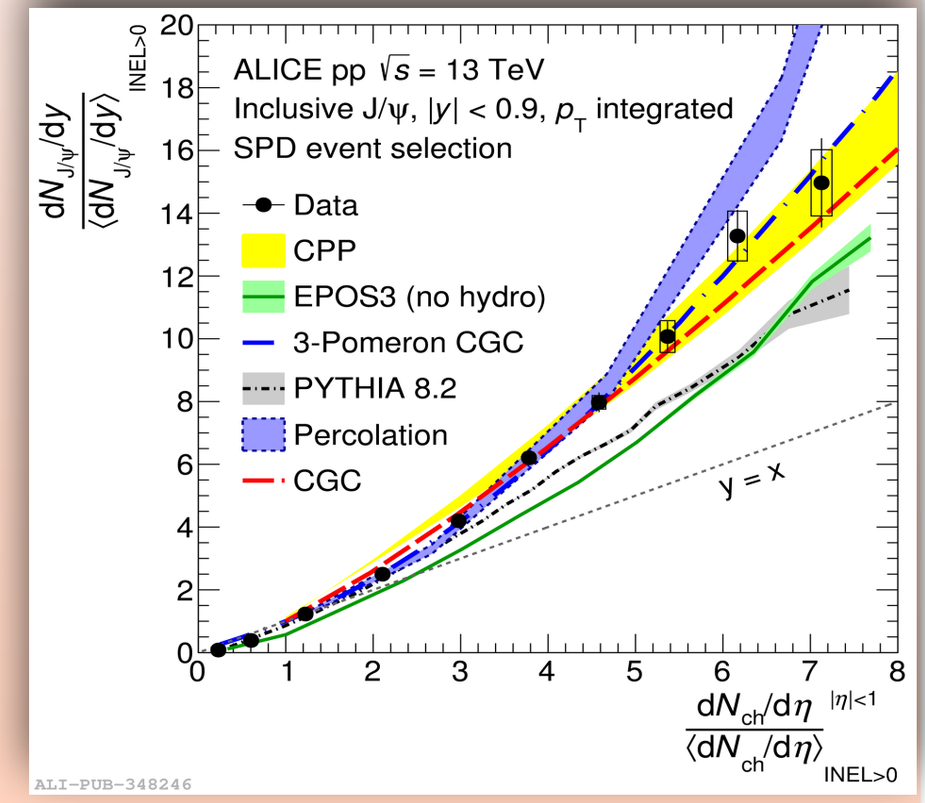

Charged-particle multiplicity dependence to study:

- Particle production mechanisms, such as Multiple Parton Interactions (MPI, several parton-parton interactions occurring in a single pp collision)
- Interplay between soft and hard processes

# PHYSICS MOTIVATIONS

Comprehensive studies performed by ALICE Collaboration on charmonium production as a function of multiplicity[1]

- J/ψ production at mid-rapidity increases faster than a linear scaling with multiplicity
- The trend of the data is fairly reproduced by various models :
  - CPP: Coherent Particle Production
  - CGC: Color Glass Condensate, gluon saturation
  - 3-Pomeron CGC: 3-gluon fusion
  - EPOS 3: parton ladders, no hydrodynamic component
  - PYTHIA 8.2: MPI
  - Percolation: color strings overlapping
- The increasing behavior in models arises from the reduction of multiplicity
- All models, except PYTHIA 8.2, only consider prompt J/ψ contribution

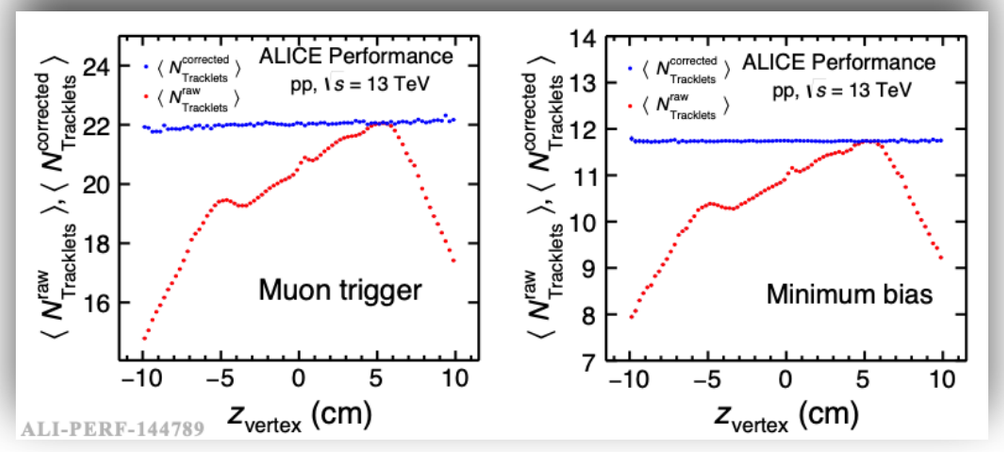



[1] ALICE Collaboration, Phys. Lett. B (2020) 135758

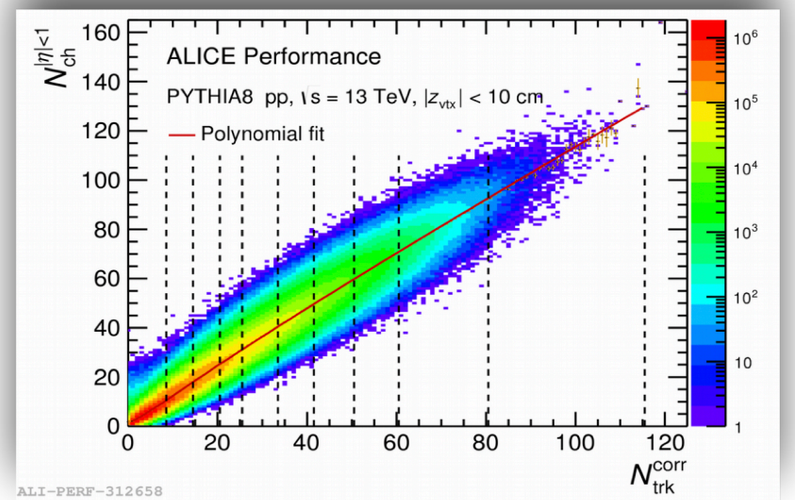
# ANALYSIS STRATEGY

Multiplicity estimation – SPD tracklets in $|\eta| < 1$

I. Equalization along the interaction vertex $z$ direction ($z_{\mathrm{vertex}}$ )




➢ Equalize the number of tracklets variation as a function of $z_{\mathrm{vertex}}$ on an event-by-event basis




II. Tracklet to charged-particle multiplicity conversion

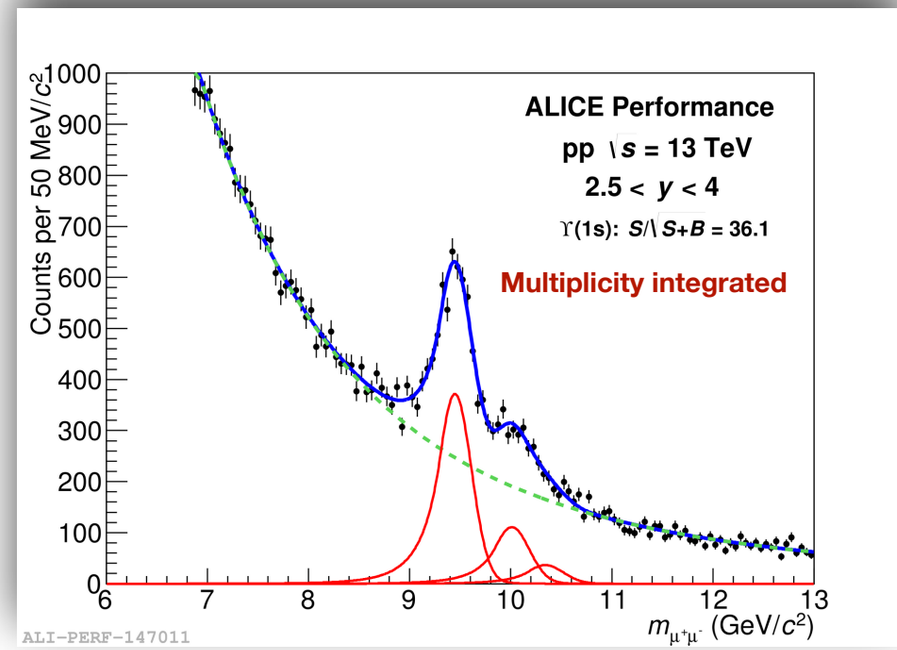
$$< N_{\mathrm{ch}} > = f( < N_{\mathrm{trk}}^{\mathrm{corr}} > )$$

➢ Based on Monte Carlo simulations which reproduce the realistic detector status

Signal extraction

➢ Clear $\Upsilon(\mathrm{nS})$ signal peaks are observed at forward rapidity

➢ A combined fit is applied to disentangle signals and background

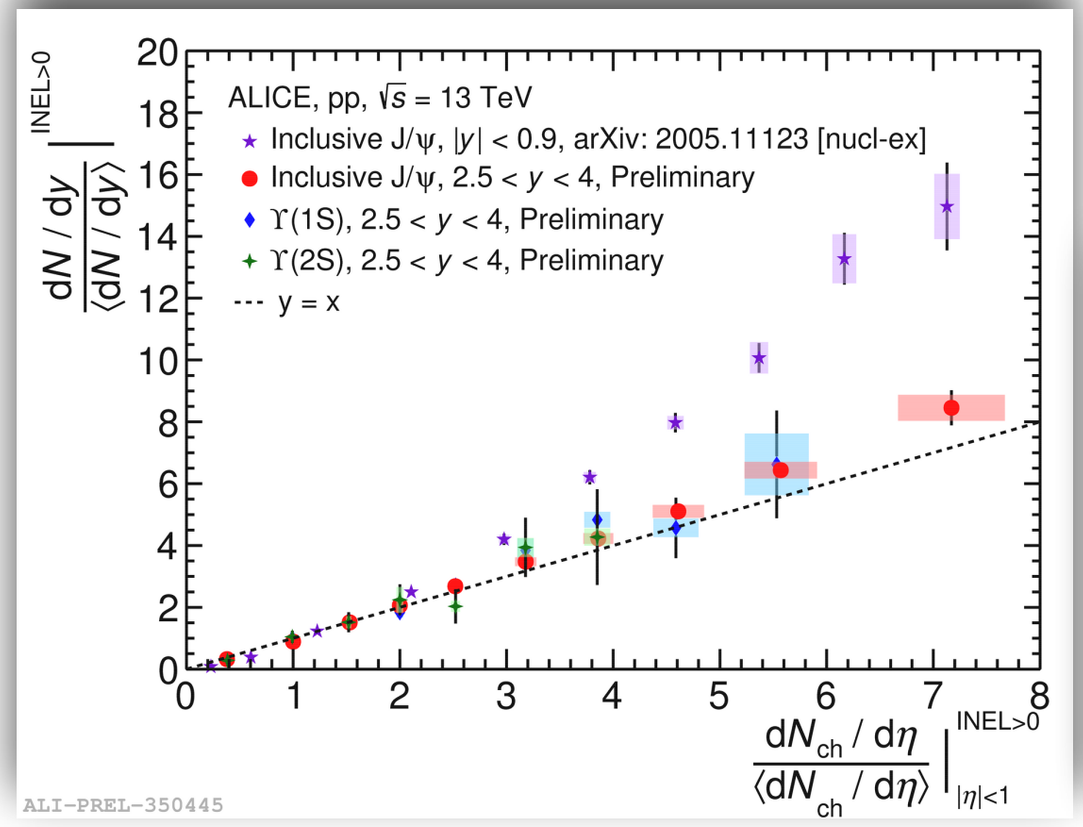


# RESULTS

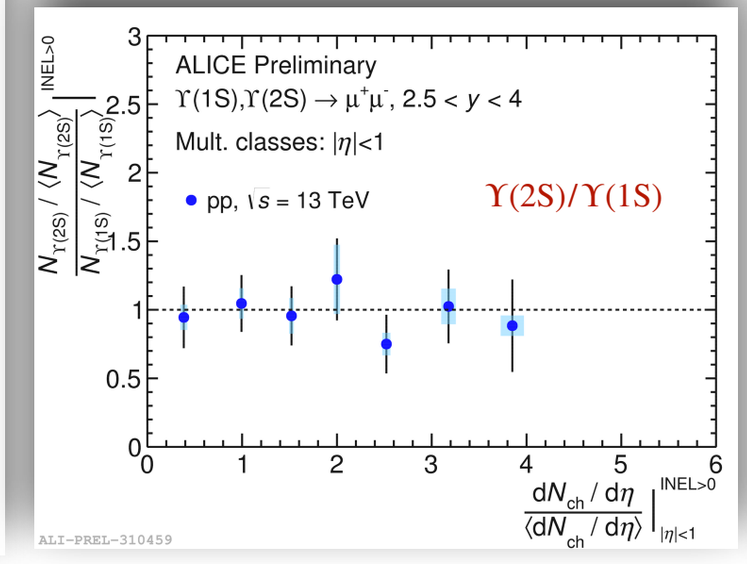
## Self-normalized $\Upsilon$(nS) and J/ψ yields as a function of multiplicity

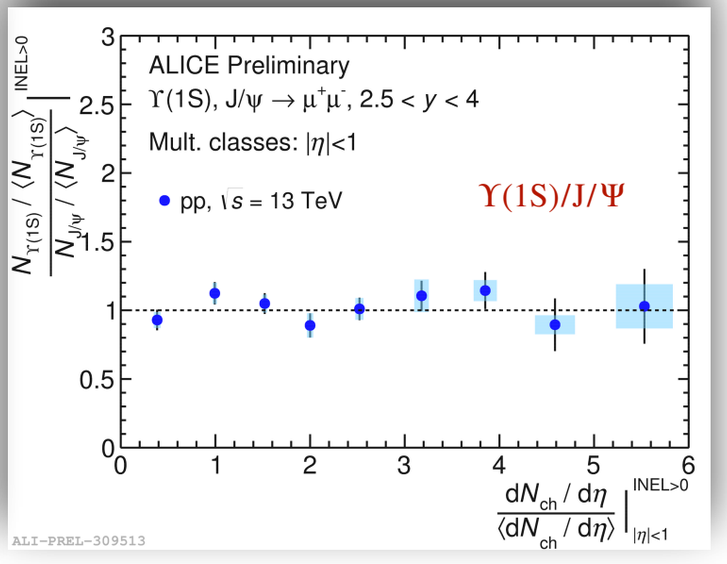
Charged-particle multiplicity is measured at mid-rapidity

- A linear increase is observed for $\Upsilon$ states and J/ψ at forward rapidity
- A faster than linear increase is shown for J/ψ at mid-rapidity




## Double yield ratios of $\Upsilon$(2S)/$\Upsilon$(1S) and $\Upsilon$(1S)/J/ψ as a function of multiplicity




- The double ratio of $\Upsilon$(2S) over $\Upsilon$(1S) is independent of multiplicity and compatible with unity within uncertainties
- The double ratio of $\Upsilon$(1S) over J/ψ is found to be unity irrespective of multiplicity within uncertainties
- No dependence on resonance mass and quark component
- The data sample for the analysis has been increased by a factor of 3 in preparation of a publication